Fisheries and Oceans Science | Pêches et Océans Sciences

C S A S | **S C C S**

Canadian Science Advisory Secretariat | **Secrétariat canadien de consultation scientifique**

Research Document 2001/066 | **Document de recherche 2001/066**

Not to be cited without permission of the authors * | Ne pas citer sans autorisation des auteurs *

Overview of Physical and Biological Oceanographic Conditions on Georges Bank

Survol des conditions océanographiques physiques et biologiques sur le banc Georges

F. H. Page[1], R. Losier[1], K. Drinkwater[2], B. Petrie[2], G. Harrison[2] and D. Sameoto[2]

[1]Department of Fisheries and Oceans, Biological Station, 531 Brandy Cove Road, St. Andrews, N.B., Can., E5B 2L9

[2]Department of Fisheries and Oceans, Bedford Institute of Oceanography, Box 1006, Halifax, N.S., Can., B2Y 4A2

* This series documents the scientific basis for the evaluation of fisheries resources in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

* La présente série documente les bases scientifiques des évaluations des ressources halieutiques du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

Research documents are produced in the official language in which they are provided to the Secretariat.

Les documents de recherche sont publiés dans la langue officielle utilisée dans le manuscrit envoyé au Secrétariat.

This document is available on the Internet at: http://www.dfo-mpo.gc.ca/csas/

Ce document est disponible sur l'Internet à:

ISSN 1480-4883
Ottawa, 2001

Canada

102-05376/

Abstract

A description of the physical and biological oceanographic conditions on Georges Bank in recent years is given and compared to historical conditions. The data examined includes hydrographic data from research vessels and ships of opportunity, sea surface temperature and chlorophyll estimates obtained from satellite remote sensing programs and plankton data from the Continuous Plankton Recorder program. The data indicate the water temperatures on Georges Bank in recent years have been about 1°C above normal. The degree of vertical stratification has been relatively constant for the past 20 years. The shelf/slope front and Gulf Stream was closer to Georges Bank in 2000 than the long-term normals and the concentration of chlorophyll on the Bank was higher in 2000 than in 1999 or 1998. The abundance of *Calanus finmarchicus* has been decreasing within the Gulf of Maine since the late 1980s. The physical conditions observed during the recent Canadian groundfish bottom-trawl surveys also reflect these patterns. Although the temperatures are above normal in recent years, they are still within the range normally associated with demersal stages of cod and haddock caught within the Georges Bank and Scotian Shelf areas.

Résumé

Les conditions océanographiques physiques et biologiques sur le banc Georges au cours des dernières années sont décrites, puis comparées aux conditions historiques. Les données examinées incluent des données hydrographiques recueillies par des navires de recherche et des navires de passage, des estimations de la température de la surface de la mer et de la concentration de chlorophylle issues de programmes de télédétection par satellite et des données sur le plancton provenant du Programme continu d'enregistrement du plancton. Les données indiquent que les températures de l'eau sur le banc Georges au cours des dernières années se situaient à environ 1 oC au-dessus de la normale, bien que le niveau de stratification verticale soit demeuré relativement constant au cours des 20 dernières années. Le Gulf Stream et le front de la pente et de la plate-forme étaient plus près du banc Georges en 2000 que la normale à long terme et la concentration de chlorophylle sur le banc était plus élevée en 2000 qu'en 1999 ou 1998. En outre, l'abondance de *Calanus finmarchicus* dans le golfe du Maine est à la baisse depuis la fin des années 1980. Les conditions physiques observées pendant les derniers relevés canadiens du poisson de fond au chalut reflètent aussi ces tendances. Bien que les températures se situaient au-dessus de la normale durant les dernières années, elles s'inscrivent encore dans la fourchette de températures normalement associées aux stades démersaux de la morue et de l'aiglefin, capturés dans les eaux du banc Georges et de la plate-forme Scotian.

INTRODUCTION

This paper describes some of the physical and biological oceanographic conditions on Georges Bank in recent years and compares these to historical conditions. The observations used to define the environmental conditions are derived from archives that include hydrographic data from research vessels and ships of opportunity, sea surface temperature (SST) and chlorophyll estimates from satellite sensors, and plankton from Continuous Plankton Recorder (CPR) records.

The overview provides an indication of the spatial and temporal trends of physical and biological indicators. It can identify unusual conditions that may signal caution when interpreting or forecasting the status of living resources. It may also be useful for generating hypotheses about environmental linkages to fish production relevant to fisheries resource management.

The initial sections of the overview contain time series of physical and biological variables for Georges Bank that have been compiled and presented at the March 2001 annual meeting of the Fisheries Oceanography Committee of the Canadian Stock Assessment Secretariat by Drinkwater et al. (2001a,b), Harrison et al. (2001) and DFO (2001). In some instances additional detail is presented here. This initial section includes data to the end of the year 2000. The material provides a broad context in which the research vessel surveys that are directed toward assessing the abundance of specific resources occur. The final section provides an overview of the near-bottom hydrographic conditions observed during the Canadian research vessel groundfish surveys conducted on Georges Bank from the year 1987 to 2001 with an emphasis on the recent years. Although less extensive, this overview follows the format used by Page, Losier and McRuer (1994, 1995, 1996, 1997a,b) who summarized the conditions in some of the previous surveys.

Although all authors have contributed material to this overview, they have not had time to review the manuscript due to the necessity for the lead author to put this overview together quickly at the last minute.

Physical Conditions

Temperature

Temperature may influence both the real and perceived production of fish by affecting fish distribution and physiological processes such as the rate of growth and maturation. Hence, knowledge of the nature of the inter-annual variability in the temperature may help lead to better understanding of fish population and community dynamics and ultimately to improvements in the management of fisheries resources.

Temperature Time Series Constructed from Archived Hydrographic Data

Drinkwater and Trites (1987) divided the Scotian Shelf, eastern Gulf of Maine and eastern Georges Bank into irregularly shaped polygons (Fig.1) and estimated the depth specific monthly mean temperatures within each of these polygons from temperature data available to them. These monthly means have been revised and updated regularly from data stored in the Bedford Institute of Oceanography's historical hydrographic database (AFAP) which is also updated with newly acquired data and synchronized with the Canadian Marine Environmental Data Service's (MEDS) database that is maintained in Ottawa. Monthly anomalies are calculated by subtracting the long-term monthly mean from each monthly mean. The long-term mean is calculated as the mean of the monthly means over the 30-year baseline period 1961-1990. The monthly anomaly time series are highly variable. This is caused in large part by the sparse nature of the data. Monthly means are often calculated from very few observations and the long-term monthly means may be derived from data from different years over the 1961-1990 period. Hence, high frequency (month to month) variations in the data should be interpreted cautiously. The running mean anomalies are much smoother and more robust. They are calculated as the 5 year running mean of the annual means where each annual mean is calculated as the mean of all the monthly means within a year. Examples of recently updated time series for several of the polygons are given in Drinkwater et al. (2001a).

The updated time series for Georges Basin, Georges Shoals and eastern Georges Bank are shown in Figures 2-4. Each figure shows the monthly anomaly and five-year running means of the annual anomalies. The temporal pattern in temperatures is similar in both series. The running mean anomalies were positive during the 1950s, negative during the 1960s and positive since the early 1970s. The monthly mean temperatures for the 3 polygons in the year 2000 were generally above long-term means (Fig.2-5).

Vertical Stratification

Vertical stratification affects many processes that may influence the growth and survival of fish during their life history. For example, stratification influences vertical mixing, the timing and magnitude of plankton blooms, perhaps the structure of the plankton community and the structure of currents.

Drinkwater et al. (2001a) calculated time series of vertical stratification for the Drinkwater and Trites (1987) geographic polygons referred to earlier. The stratification index they used was defined from the archived hydrographic data as the difference in the monthly mean density of the seawater at 0 and 50m depth. The units of the index are (g/ml)/m and a value of 0.1 (g/ml)/m corresponds to a difference of 0.5 sigma-t units over the 50m-depth interval. As with temperature, they calculated the monthly anomaly in density stratification by subtracting the 1961-1999 monthly mean from each individual monthly mean. The annual

anomalies were calculated as the mean of the available monthly means within each year. These annual mean anomalies were then smoothed with a five-year running mean.

The five-year running mean time series of the annual anomalies in the vertical stratification index are presented in Fig. 6 for the Georges Basin, Georges Shoals, Eastern Georges Bank and Northeast Channel polygons. In all series the stratification has varied by less than 0.01 (g/ml)/m or less than 0.05 sigma-t units per 50m. Each series shows relatively large variability during the 1950s, 1960s and early 1970s and a pronounced lack of inter-annual variability since about 1975. This pattern is not like that on the Scotian Shelf. Stratification on the Scotian Shelf in recent years has been enhanced and characterized by positive anomalies of about 0.05 (g/ml)/m (Drinkwater et al. (2001a).

Satellite Derived SST

The above environmental indicators are based on data collected at sea from various platforms. The data is often limited in space and time. A more complete spatial and temporal sampling for the sea surface is obtained from environmental indices derived from satellites. We therefore include satellite based indicators of sea surface temperature (SST).

Sea Surface Temperatures (SST) estimated from satellite observations made by the Jet Propulsion Laboratory are archived at the Bedford Institute of Oceanography. The data series begins in October 1981. Mason et al. (1999) and Petrie and Mason (2000) provide a discussion of their accuracy and utility as a climate indicator. Drinkwater et al. (2001b) calculated monthly mean SST estimates from the archived data for 23 geographic boxes distributed throughout Atlantic Canada (Fig.7). Within each box the long-term monthly means are derived for the period 1981-2000 and the monthly anomalies were calculated by subtracting the long-term means from each monthly mean. The time series of the annual anomalies for the Georges Bank box are plotted in Fig. 8. The annual SST anomaly in the years 1999 and 2000 was about +1°C and higher than all previous years. This pattern is similar to that on the Scotian and Newfoundland Shelves (Drinkwater et al. 2001b).

Frontal Analysis: Shelf/Slope Front

The waters on the Scotian Shelf and in the Gulf of Maine have distinct temperature and salinity characteristics from those found in the adjacent offshore waters. The boundary between the shelf and offshore slope waters is regularly detected in satellite thermal imagery. Positions of this boundary, referred to as the shelf-slope front, were digitized from satellite derived SST charts for the region between 50°W and 75°W for the years 1973 to 1992 (Drinkwater et al., 1994). From January 1973 until May 1978, the charts covered the region north to Georges Bank, but in June 1978 the areal coverage was extended to 55°W.

Monthly mean positions of the shelf/slope front in degrees latitude at each degree of longitude were estimated. NOAA updated this dataset until October 1995. A commercial company has continued the analysis but did not begin until April 1996. Their initial charts did not contain data east of 60°W but within a year were extended east to 55°W. Data for 2000 have been digitized, estimates of monthly mean positions determined and anomalies relative to the 20-year period, 1978 to 1997, were calculated. During the past 2 years, the charts only extend east to 56°W.

The overall mean position of the Shelf/Slope front and annual mean position for the year 2000 is shown in Figure 9. Although not evident in the annual mean position, the front is generally farthest offshore in winter and farthest onshore in late summer and early autumn. During the year 2000, the shelf/slope front was shoreward of its long-term mean position except at its eastern end. The largest positive deviations occurred just east of Cape Hatteras. The time series of the annual mean position (averaged over 56°W-75°W) shows the front was at a minimum seaward location in 1985 and again in 1993 (Fig. 9). Since 1993, the front moved steadily seaward approximately 40 km, reaching its most southerly position in 1997. From 1998 to 2000, the position of the Shelf/Slope front moved northward with the largest increase from 1998 to 1999. The position in 2000 was slightly farther north than in 1999.

Frontal Analysis: North wall of the Gulf Stream

The position of the northern boundary or "wall" of the Gulf Stream was also determined from satellite imagery by Drinkwater et al. (1994) up to 1992 and has been updated in a manner similar to that for the shelf/slope front. The average position of the north wall of the Stream leaves the shelf break near Cape Hatteras (75°W) runs toward the northeast until about 62°W where it begins to run more toward the east (Fig. 10). During the year 2000, the average position of the Stream was shoreward of its long-term mean position at all degrees of longitude except 75°W and 64°W. The time series of the position shows the Stream was located south of its mean position during the late-1970s and early 1980s, near the long term mean through the mid-1980s and north of it during the late-1980s and into the first half of the 1990s (Fig.10). The annual anomaly of the Gulf Stream was at its most northerly position in 1995. A rapid movement to the south followed in 1996. This position was maintained through 1997 and 1998. The 1996 position is not well defined, however, since it is based upon only three months of data (October to December). In 1999, the average position of the front moved shoreward but remained south of the mean. By 2000 the position of the Gulf Stream was shoreward of its long-term mean and was the 2nd highest positive anomaly behind 1995.

Biological Conditions

Phytoplankton

The state of ocean at the primary and secondary trophic levels within the waters off Atlantic Canada are just beginning to be assessed on a regular basis as part of a DFO Atlantic Zonal Monitoring Program (AZMP). Unforunately, the program does not have extensive biological sampling on Georges Bank. However, satellite data derived from the SeaWifs satellite system are used to estimate phytoplankton biomass (chlorophyll concentrations) for the entire continental shelf region off Atlantic Canada on a bi-weekly basis. Subsets of this broad geographic area have been defined for more detailed analyses (Fig. 7). These areas are the same as used for the analyses of the Jet Propulsion Laboratory SST dataset described earlier. Within each of the subset areas the time series of SST, chlorophyll and apparent primary production have been estimated. The time series begin in September 1997 and extend to the present. Statistics concerning the annual amplitude and phasing (timing) of the annual chlorophyll cycle in various areas are calculated. The data and some statistics for the Georges Bank box are discussed below. A more extensive description of the data and the results for the entire Atlantic Canada region are given in Harrison et al. (in prep) and DFO (2001).

The time series of estimated chlorophyll concentration in the Georges Bank box is shown in Fig. 11. The chlorophyll concentration ranges from about 1 to 5 μg/l. There is a suggestion of a low frequency trend. The low concentrations during early 1998 increased to higher values in early 1999, decreased throughout the rest of 1999 and increased again to the largest values observed in the series in the year 2000. In 2000 the estimated peak concentration of chlorophyll was greater than 5 μg/l (=mg/m^3) whereas in 1999 the peak was less than 5ug/l. In 1999 there is a suggestion of a spring and fall bloom. The annual maximum concentration generally occurs in late March on Georges Bank and becomes progressively later toward the north (Fig. 12).

Zooplankton

Records from the continuous plankton recorder (CPR) program are being examined as part of the Atlantic Zonal Monitoring program in an effort to get an indication of the temporal variation in zooplankton abundance within the shelf waters off Atlantic Canada. The sampling tracks for the CPR are shown in Fig. 13. The tracks crossed over Georges Bank mainly during 1991-1998. From 1961-1976 the tracks were primarily across the Gulf of Maine. The time series of *Calanus* abundance is shown in Fig. 14. The data suggest that *Calanus* within the Gulf of Maine, and perhaps on Georges Bank, peaked in the late 1980s and that it has been decreasing ever since.

Physical Conditions During the Canadian Groundfish Spring Surveys

Canada has conducted a spring bottom-trawl survey on Georges Bank since 1987. It is a stratified random survey in which Georges Bank is divided into eight strata (5Z1-8; Fig. 15). Hydrographic data are taken during the surveys using a CTD (conductivity, temperature, depth profiler). Overviews of the near-bottom temperature and salinity data from the surveys up until 1997 have been given by Page, Losier and McRuer (1994, 1995, 1996, 1997a,b). Overviews have not been produced recently.

The nature of the sampling effort has varied throughout the survey. The timing of the survey has varied from about day 40 (early Feb) to day 80 (mid-Mar., Fig. 16). For example, the date of the survey decreased from 1987 to 1991, increased until 1993, decreased in 1994 and increased until 1997. The dates from 1998 to 2001 have been reasonably constant and consistent with the earlier dates in the survey series. The temporal variability in the survey sampling effort results in inter-annual differences in temperatures being masked by the variability associated with the annual evolution of temperature field in space and time. For example, the inter-annual trend in temperature within several of the strata is consistent with the changing of the survey timing in relation to the seasonal warming cycle (Page, Losier and McRuer 1994, 1995, 1996). Hence, the temperature variability encountered by the survey may not be indicative of real inter-annual variability in the hydrographic climate of Georges Bank. However, it is indicative of the inter-annual variation in the conditions at the time in which the various fish species were captured during the survey series. No attempt has been made to correct the time series for this timing effect.

The number of hydrographic samples per strata has decreased over the survey series (Fig. 17). The number of samples was reduced in strata 5Z1, 5Z3, 5Z7 and 5Z8 in 1992. A large reduction occurred in 5Z2 in 1996. The numbers have steadily decreased in 5Z4 and 5Z6 since 1995. This reduction has resulted in a poorer spatial coverage (Fig. 18). In 1992 the spatial coverage in strata 5Z3, 5Z5 and 5Z7 and 5Z8 was poor. In 1993 and 1994 no hydrographic data were gathered from strata 5Z5-8 and the spatial coverage in strata 5Z4 was very limited. In the 1995 through 1997 surveys the spatial coverage was somewhat improved but since 1999 the coverage in strata 5Z5-8 has been sparse. This reduction is associated with the emphasis of the survey on the Canadian portion of Georges Bank.

Over the entire time period of the surveys, the near-bottom temperatures within the survey domain have ranged from about 3°C to 14°C (Fig. 19). The highest temperatures are found in the deep strata (5Z1, 5Z8) located along the southern flank of the bank. Near-bottom temperatures within the other strata have ranged from about 3°C to 8°C. The temperatures in the year 2001 survey were above the series median for most strata. Relative to previous surveys, there were

few temperatures below 5°C (Fig. 20). The time series of unweighted (Fig. 21) and strata area weighted (Fig. 22) near-bottom temperatures for 5Z indicate that the median and mean temperatures in the last three surveys have been the warmest in the survey series (Fig. 21). This pattern may be influenced by the changes in the sample coverage (Fig. 21). The strata specific time series of near-bottom temperatures are given in Fig. 23. Much of the variability in some of the strata is due to the large range in near-bottom depths sampled in these strata (Page et al. 1996, 1997a,b).

Near-bottom salinities in 2001 also tended to be above the series means and medians, but not to as great as an extent as temperature (Fig. 19 and 20). The time series of unweighted (Fig. 21) and strata area weighted (Fig. 22) near-bottom salinities indicate that the median and mean salinities have varied cyclically over the years. The salinities in the last two surveys have been relatively high. As with temperature the decrease in 1993 is associated with a very limited sampling effort in that year. The strata specific time series of near-bottom salinities are given in Figure 24.

Summary and Discussion

The water temperatures on Georges Bank in recent years and in recent Canadian groundfish bottom-trawl surveys have been relatively warm. This has been evident in both in situ observations and estimates derived from remote sensors. The temperatures however, are still well within the temperature range normally associated with the demersal stages of cod and haddock caught within the 5Z and 4VWX areas (Page et al. 1994, Smith et al. 1994). Hence the conditions in 2000 should not have influenced the relative catchability of the fish.

The estimates of chlorophyll concentration suggest that phytoplankton biomass was higher in the year 2000 than in 1999. The Continuous Plankton Recorder data suggest the biomass of *Calanus* has been decreasing within the Gulf of Maine during the past several years. Unfortunately, changes in the location of the CPR line, mean that data from directly over Georges bank is not longer collected.

The timing of the Canadian Spring groundfish survey coincides closely with the timing of cod and haddock spawning period on Georges Bank as indicated by the presence of eggs in the MARMAP icthyoplankton survey series (Page, Losier and Berrien 1997). The median date for spawning within 5Zjm is about day 75 (mid-March) for cod and day 80 (mid-March) for haddock. The survey dates range from about day 40 to 80. The spread in the spawning time is considerably different between the two species. Cod spawning extends from about late November to the late April, whereas haddock spawning is mainly between late-February and late March. It is interesting to speculate that some of the inter-annual variability in survey abundance estimates may be related to the variation in the timing of the

survey relative to fish migration and behavior related to the annual spawning cycle. Unfortunately, we are not aware of evidence to support or dispute this situation.

Acknowledgements

The data summarized in this manuscript were collected by many people, many whom are acknowledged in the references cited. In particular, importance were the ships crew and scientific staff from the Marine Fish (MFD) and Ocean Sciences (OSD) Divisions from the Department of Fisheries and Oceans, Maritimes Region. Key personnel included Jeff McRuer (MFD), Jeff Spry (OSD) and Kevin Pauly (OSD). The groundfish survey data were also collected with the help of the officers and crew of the CCV *A.J. Needler*.

References

DFO. 2001. Chemical and biological oceanographic conditions 2000 – Maritimes Region. DFO Science Stock Status Report xx-xx (2001).

Drinkwater, K.F., R.A. Myers, R.G. Pettipas and T.L. Wright. 1994. Climatic data for the Northwest Atlantic: The position of the shelf/slope front and the northern boundary of the Gulf Stream between 50°W and 75°W, 1973-1992. Can. Data Rept. Fish. Ocean. Sci. 125: 103 pp.

Drinkwater, K.F., B. Petrie, R.G. Pettipas, L. Petrie and V. Soukhovtsev. 2001a. Physical Oceanographic Conditions on the Scotian Shelf and in the Gulf of Maine during 2000. Canadian Stock Assessment Secretariat Research Document 2001/xxx.

Drinkwater, K.F., B. Petrie, R.G. Pettipas and W.M. Petrie. 2001b. Overview of Meteorological, Sea-Ice and Sea-Surface Temperature Conditions off Eastern Canada during 2000. Canadian Stock Assessment Secretariat Research Document 2001/xxx.

Drinkwater, K.F. and R.W. Trites. 1987. Monthly means of temperature and salinity in the Scotian Shelf region. Can. Tech. Rep. Fish. Aquat. Sci. 1539: 101p.

Harrison et al. in prep. Chemical and biological oceanographic conditions in the year 2000 in the Maritimes Region of Atlantic Canada. Canadian Stock Assessment Secretariat Research Document 2001/xxx.

Mason, C.S., B. Petrie and B.J. Topliss. 1999. Satellite measurements of sea-surface temperature: an application to regional ocean climate. NAFO Sci. Coun. Studies, 32: 45-54.

Page, F.H., R. Losier and J. McRuer. 1994. Overview of temperature and salinity conditions within NAFO Areas 4VWX and 5Z, during Canadian 1993 groundfish research vessel surveys. DFO Atl. Fish. Res. Doc. 94/94, 53 p.

Page, F.H., R. Losier and J. McRuer. 1995. Overview of temperature and salinity conditions within the Scotia-Fundy Region, NAFO Areas 4VWX and 5Z, during Canadian 1994 groundfish research vessel surveys. DFO Atl. Fish. Res. Doc. 95/138, 63 p.

Page, F.H., R. Losier and J. McRuer. 1996. Overview of near-bottom water temperature and salinity conditions observed during the groundfish research vessel surveys conducted within the Scotia-Fundy Region, NAFO Areas 4VWX and 5Z in 1995. DFO Atl. Fish. Res. Doc. 96/20, 68p.

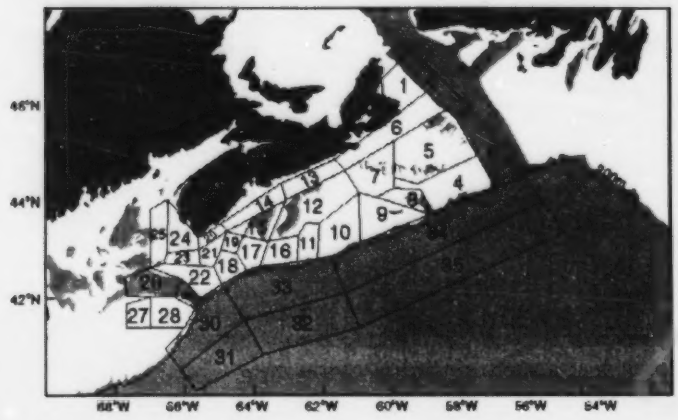
Page, F.H., R. Losier and J. McRuer. 1997a. Overview of 1996 hydrographic sampling effort and near-bottom water temperature and salinity conditions during the Canadian spring research vessel groundfish surveys conducted on the eastern Scotian Shelf (4VsW) and Georges Bank (5Z). Can. Stock Assess. Secretariat Res. Doc 97/12, 29p.

Page, F.H., R. Losier and J. McRuer. 1997b. Overview of 1997 hydrographic sampling effort and near-bottom temperature and salinity conditions during the Canadian research vessel groundfish surveys conducted during the spring on the eastern Scotian Shelf (4VsW) and Georges Bank (5Z). Can. Stock Assess. Secretariat Res. Doc 97/127, 29p.

Page, F., R. Losier, S. Smith, and K. Hatt. 1994. Associations between cod, and temperature, salinity and depth within the Canadian Groundfish bottom-trawl surveys (1970-93) conducted within NAFO Divisions 4VWX and 5Z. Can.Tech. Rep. Fish. Aquat. Sci. 1958: vii + 160 p.

Petrie, B. and C.S. Mason. 2000. Satellite measurements of sea-surface temperature: an application to regional ocean climate. Can. Stock Assess. Secretariat Res. Doc. 2000/061, 24 pp.

Smith, S., R. Losier, F. Page and K. Hatt. 1994. Associations between haddock, and temperature, salinity and depth within the Canadian Groundfish bottom-trawl surveys (1970-93) conducted within NAFO Divisions 4VWX and 5Z. Can. Tech. Rep. Fish. Aquat. Sci. 1959: vi + 70 p.



1. Sydney Bight
2. N. Laurentian Channel
3. S. Laurentian Channel
4. Banquereau
5. Misaine Bank
6. Canso
7. Middle Bank
8. The Gully
9. Sable Island
10. Western Bank
11. Emerald Bank
12. Emerald Basin
13. Eastern Shore
14. South Shore
15. Lahave Basin
16. Saddle
17. Lahave Bank
18. Baccaro Bank
19. Roseway Bank
20. Shelburne
21. Roseway Basin
22. Browns Bank
23. Roseway Channel
24. Lurcher Shoals
25. E. Gulf of Maine
26. Georges Basin
27. Georges Shoal
28. E. Georges Bank
29. N.E. Channel
30. Southern Slope
31. Southern Offshore
32. Central Offshore
33. Central Slope
34. Northern Slope
35. Northern Offshore

Figure 1: Areas on the Scotian Shelf and eastern Gulf of Maine from Drinkwater and Trites (1987).

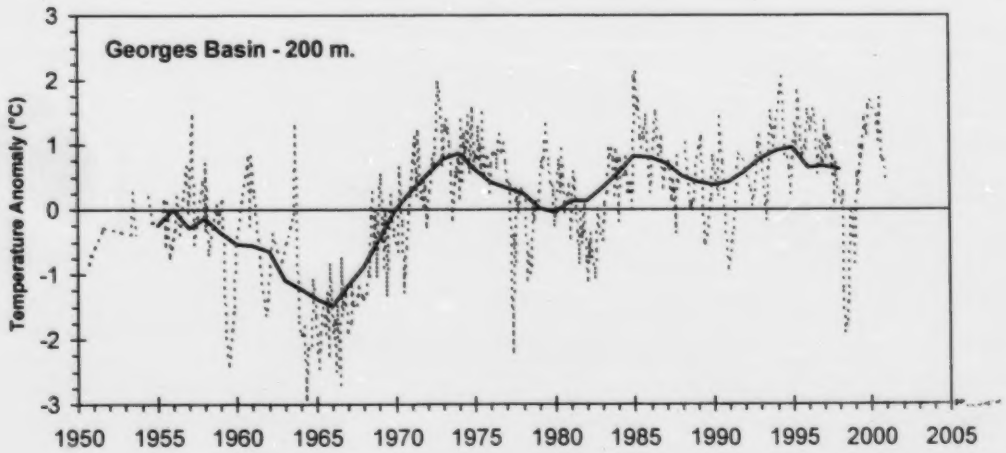


Figure 2: Time series of monthly mean temperature anomalies (dashed lines) at 200m in Georges Basin (polygon 26) and their 5-year running means (solid line).

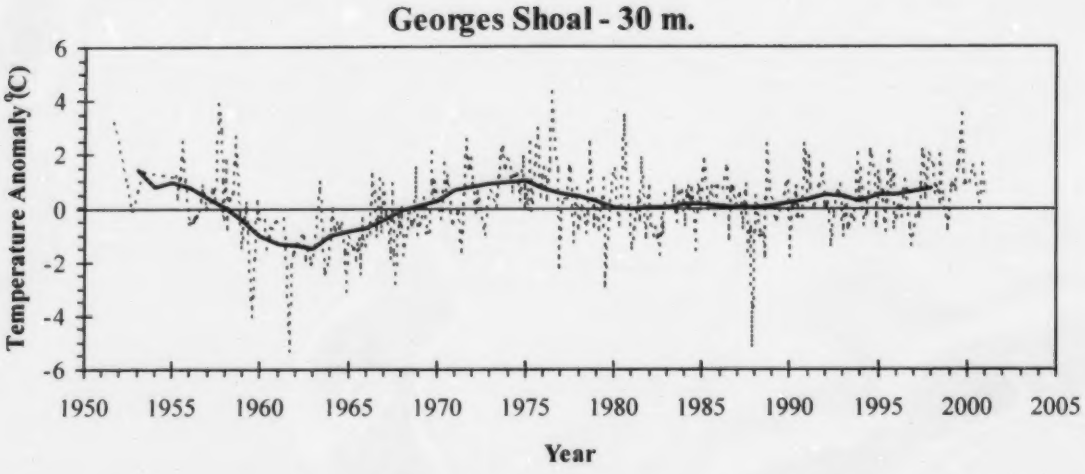


Figure 3: Time series of monthly mean temperature anomalies (dashed lines) at 30m on Georges Shoals (polygon 27) and their 5-year running means (solid line).

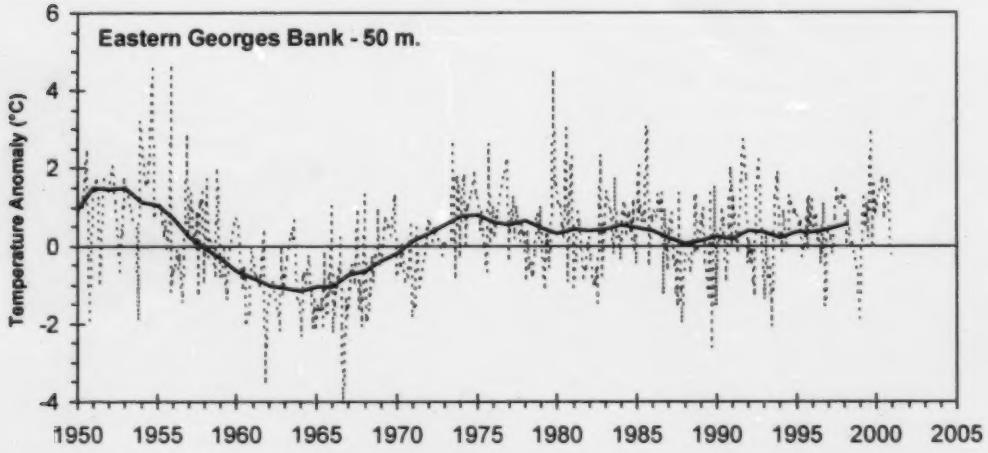


Figure 4: Time series of monthly mean temperature anomalies (dashed lines) at 50m on eastern Georges Bank (polygon 28) and their 5-year running means (solid line).

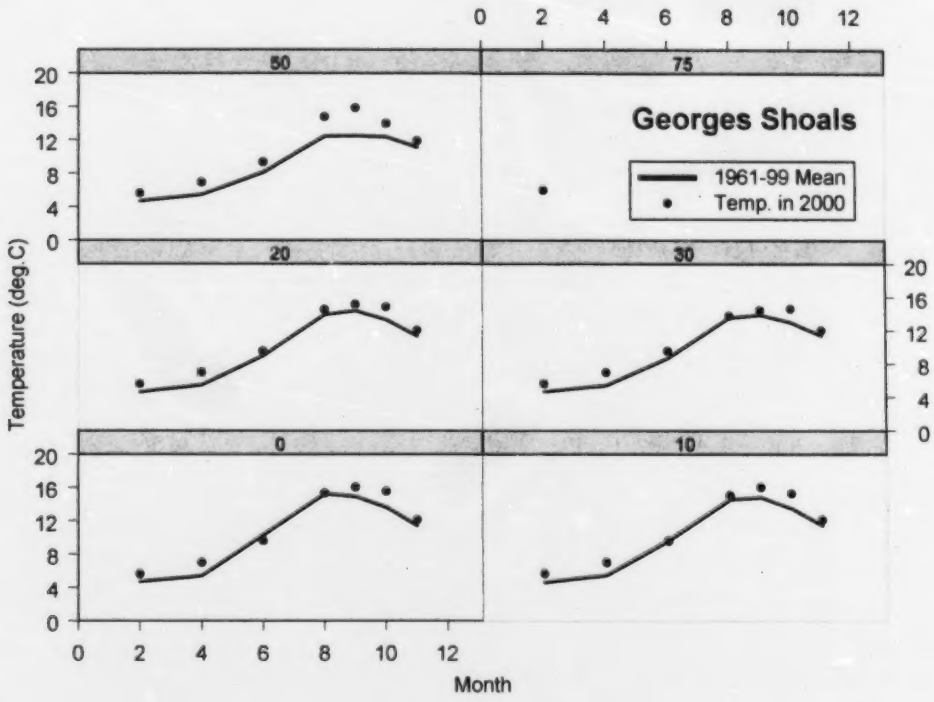


Figure 5. Monthly mean temperatures at several depths in the year 2000 within the Drinkwater and Trites (1987) Georges Shoal polygon number 27. The solid line represents the long-term monthly mean temperature at each depth and the solid dots are the monthly means for the year 2000. A baseline mean was not calculated for the 75m depth bin. The numbers within the bars above each panel indicate the depth (m) bin.

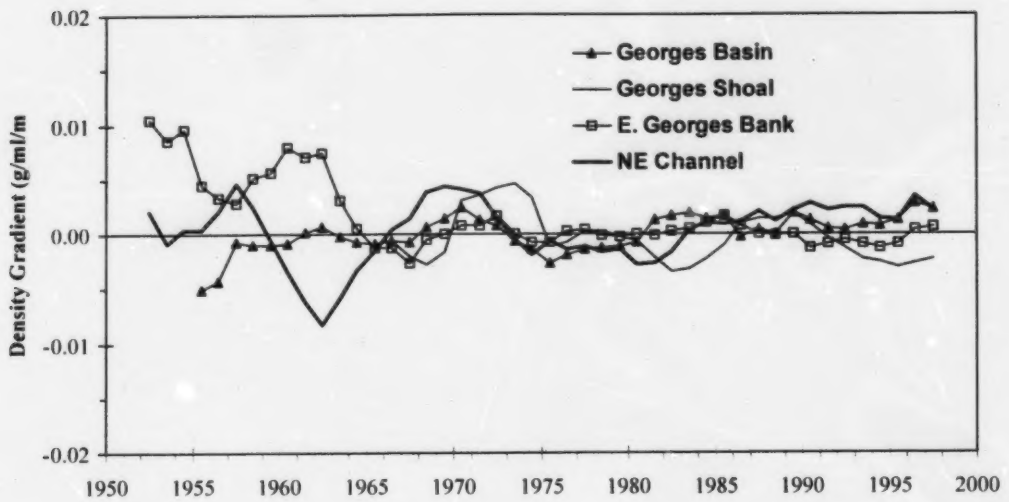


Figure 6. Five-year running means of the annual anomalies of the density gradient between the surface and 50 calculated for the Georges Bank, Georges Basin and Northeast Channel areas.

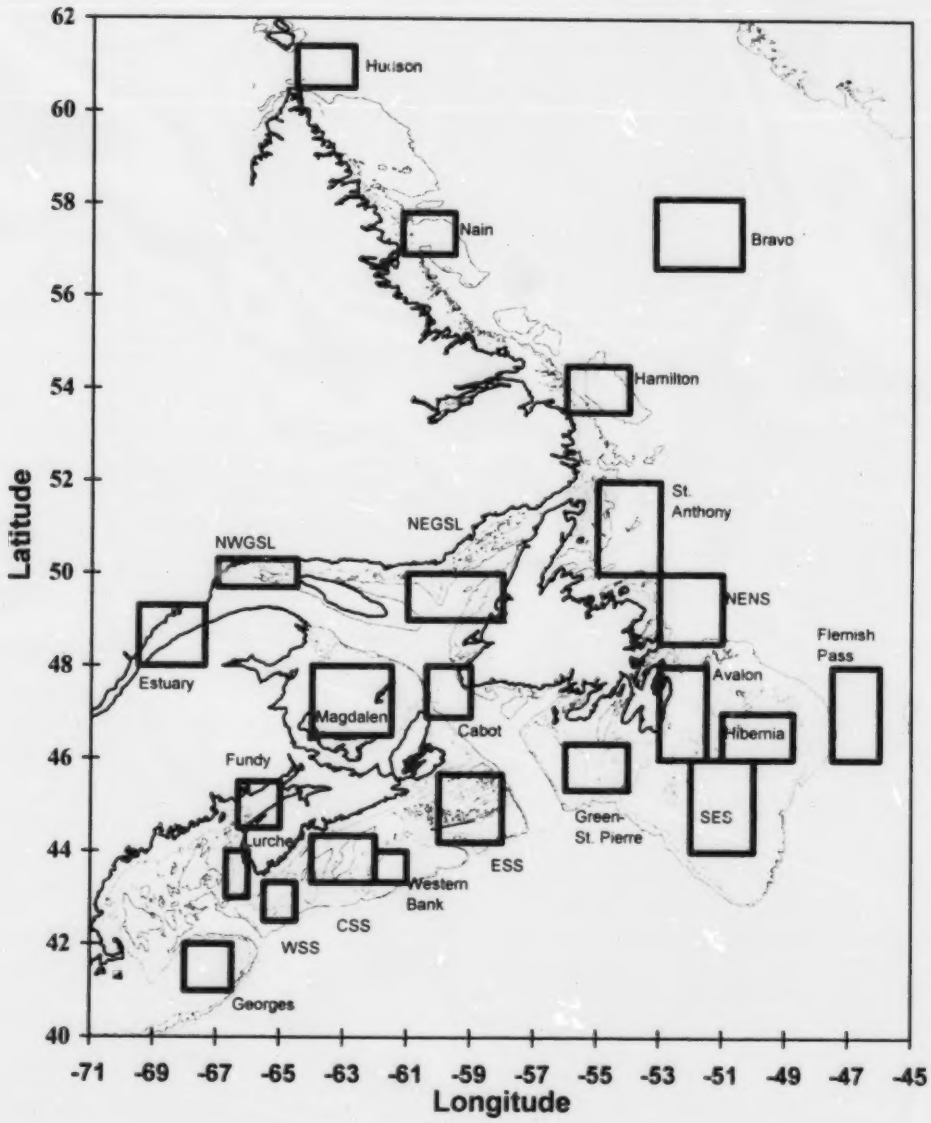


Figure 7. The areas in the northwest Atlantic used for extraction of sea-surface temperature.

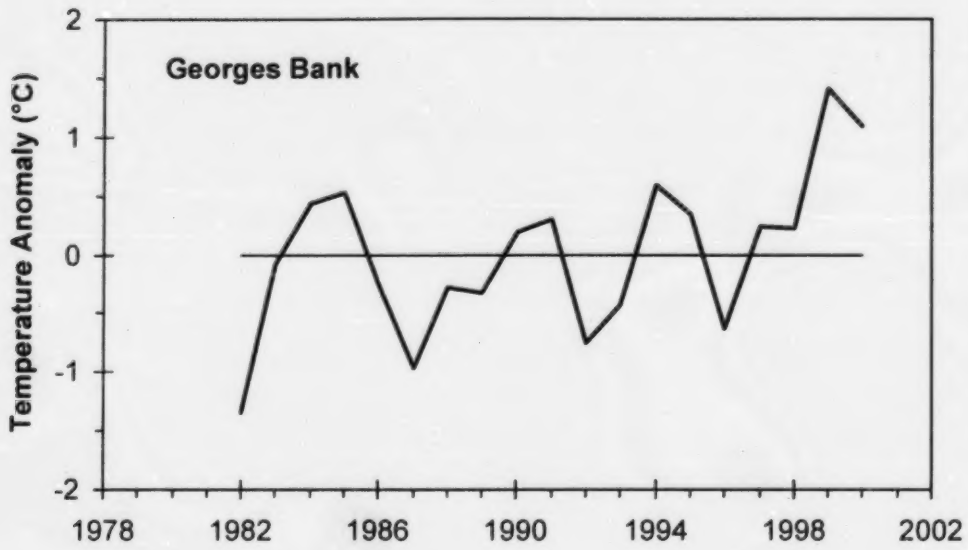
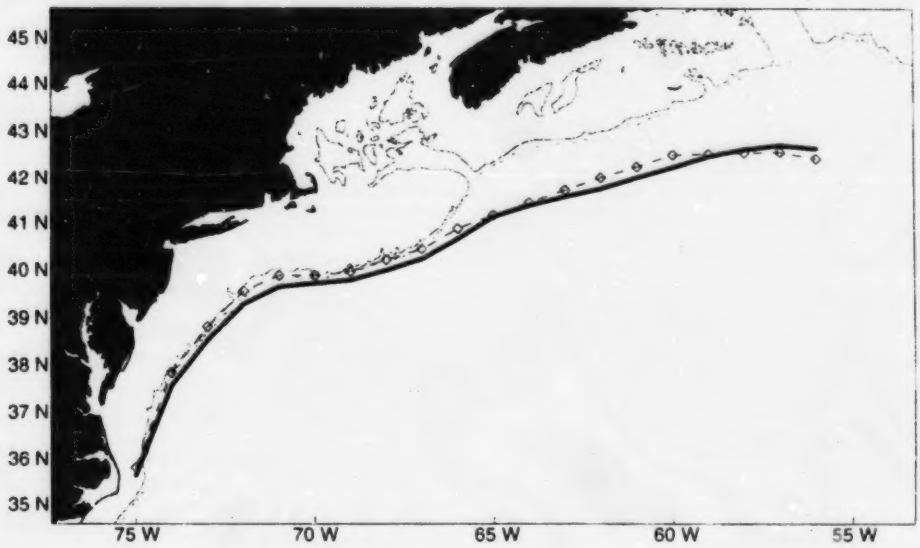


Figure 8. The annual sea-surface temperature anomalies for the Georges Bank region estimated from satellite imagery obtained through the Jet Propulsion Laboratory (JPL).



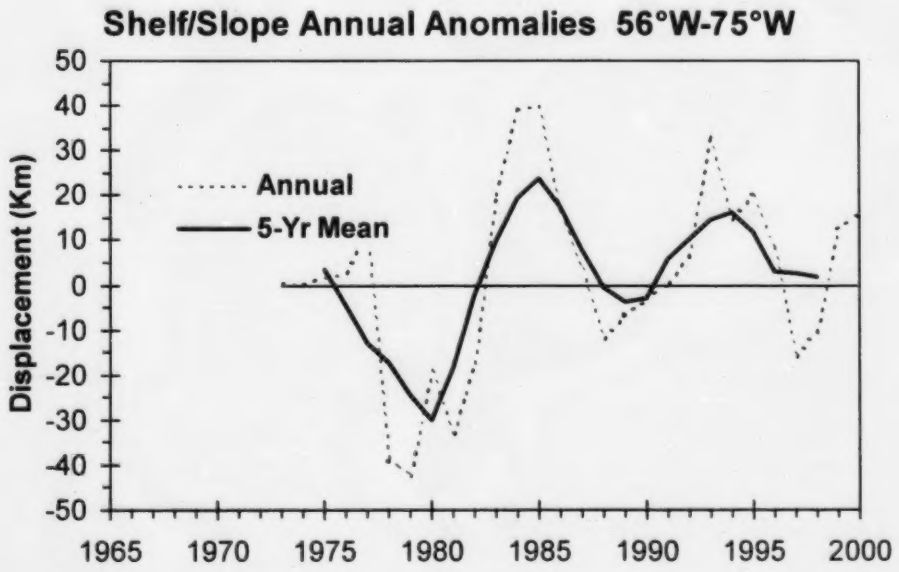
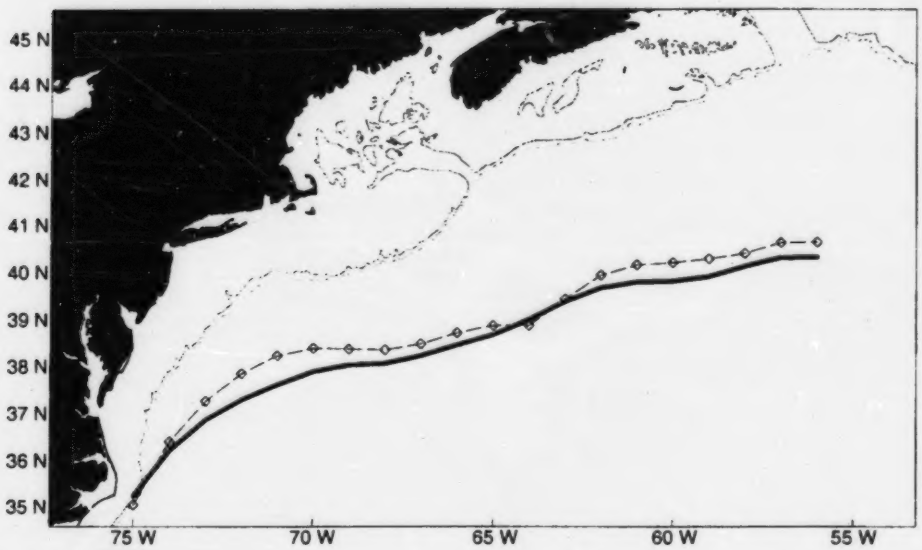


Figure 9. The 2000 (dashed line) and long-term mean (1973-97; solid line) positions of the shelf/slope front (top panel) and the time series of the annual anomaly of the mean (56°-75°W) position of the shelf/slope front (bottom panel).



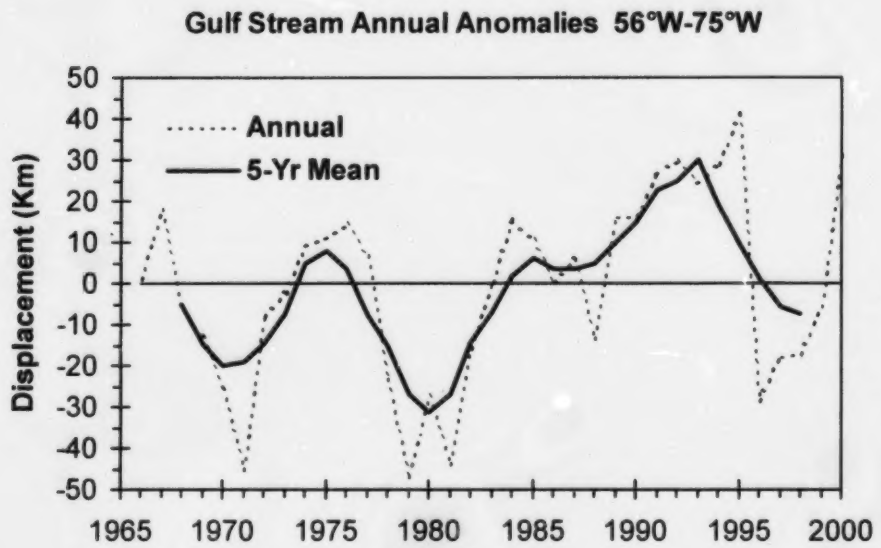


Figure 10: Positions of the northern edge of the Gulf Stream in the year 2000 (top panel; 2000 dashed line;1973-97; solid line) and the time series of the anomaly of the annual mean (lower panel) calculated for the 56°-75°W position of the Gulf Stream front.

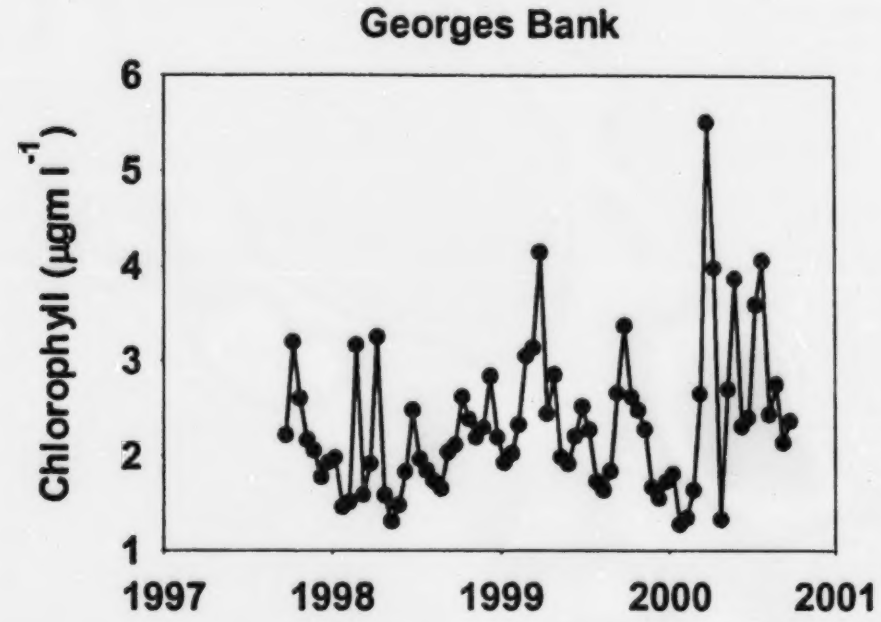


Figure 11: Time series of bi-weekly mean chlorophyll concentrations as estimated from SeaWif images for the years 1997-2000. The chlorophyll units are µg/L (=mg/m^3).

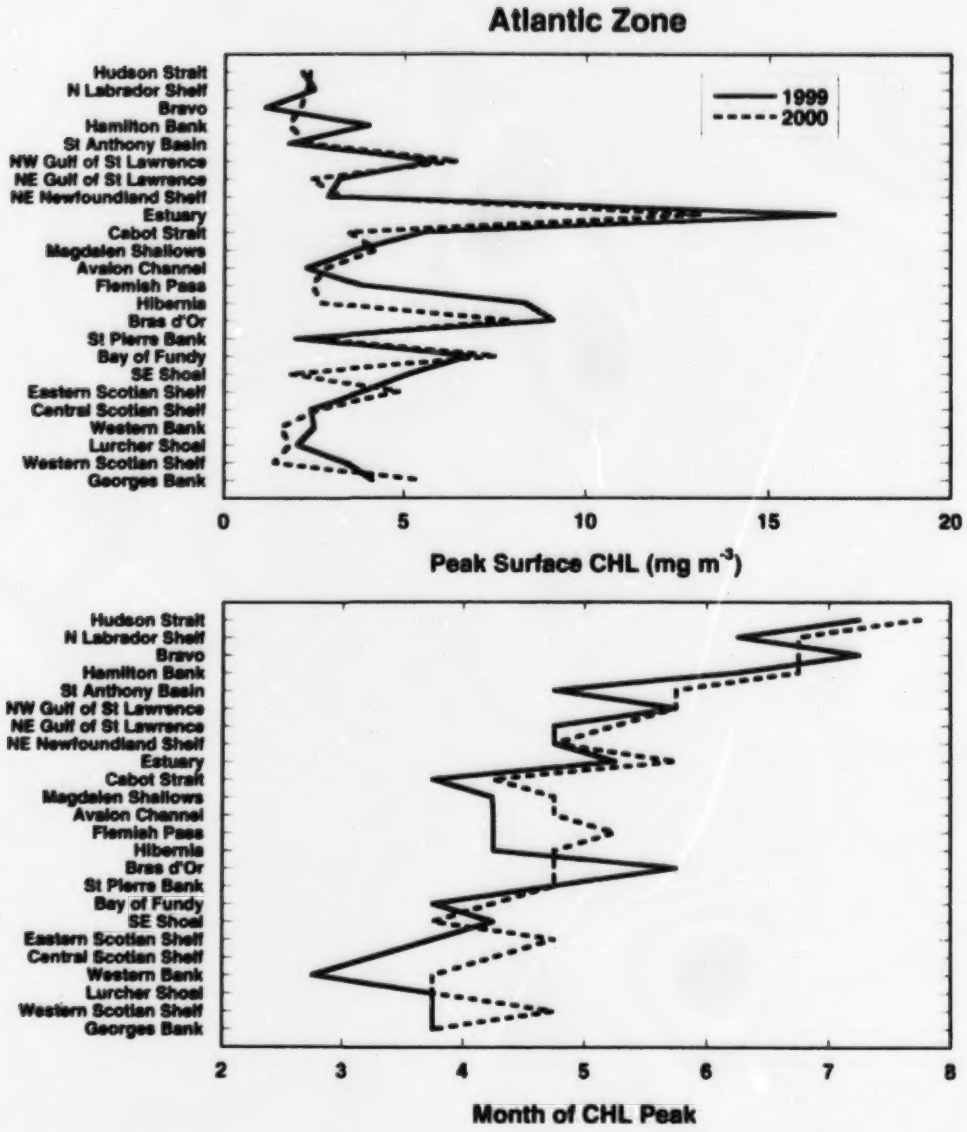


Figure 12: The time of the annual maximum of bi-weekly mean chlorophyll concentrations as estimated from SeaWiff images for the years 1997-2000.

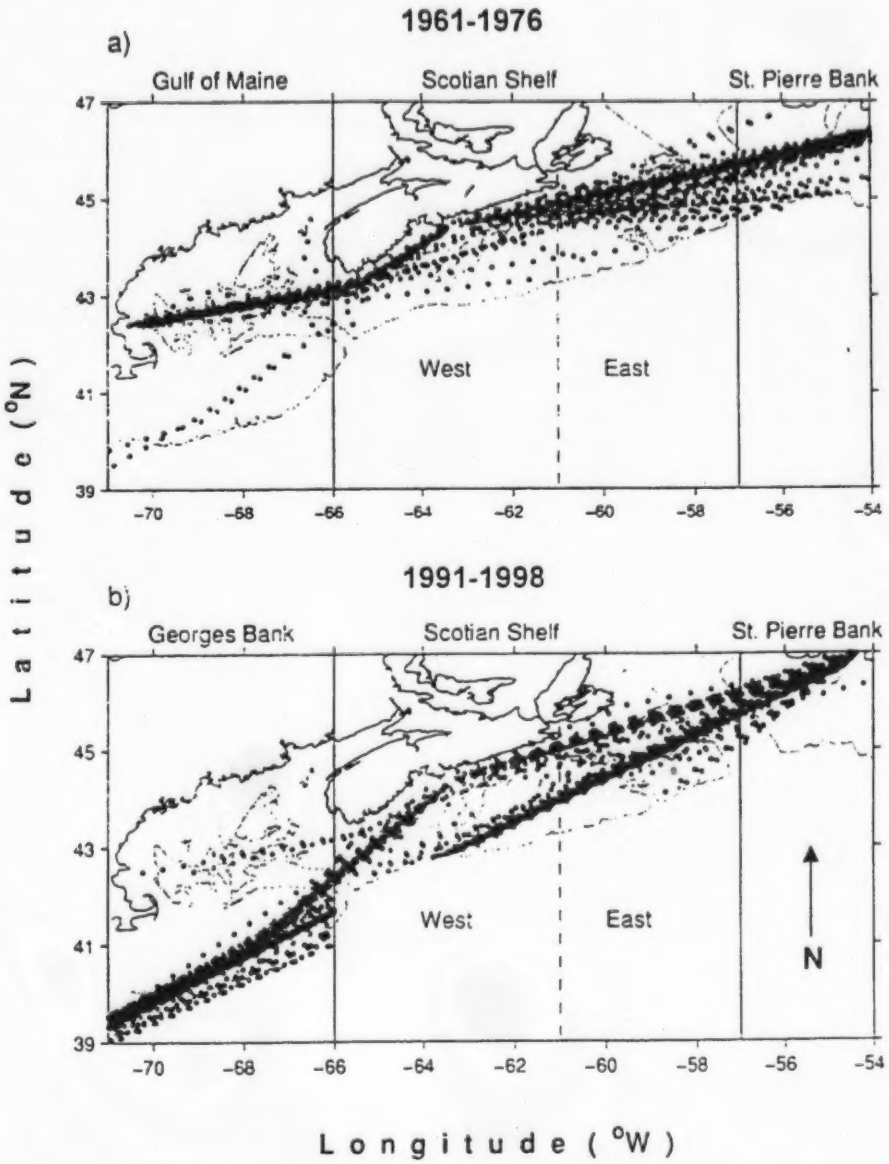


Figure 13: Sampling transects occupied by the Continuous Plankton Recorder Program in the Gulf of Maine and Scotian Shelf region.

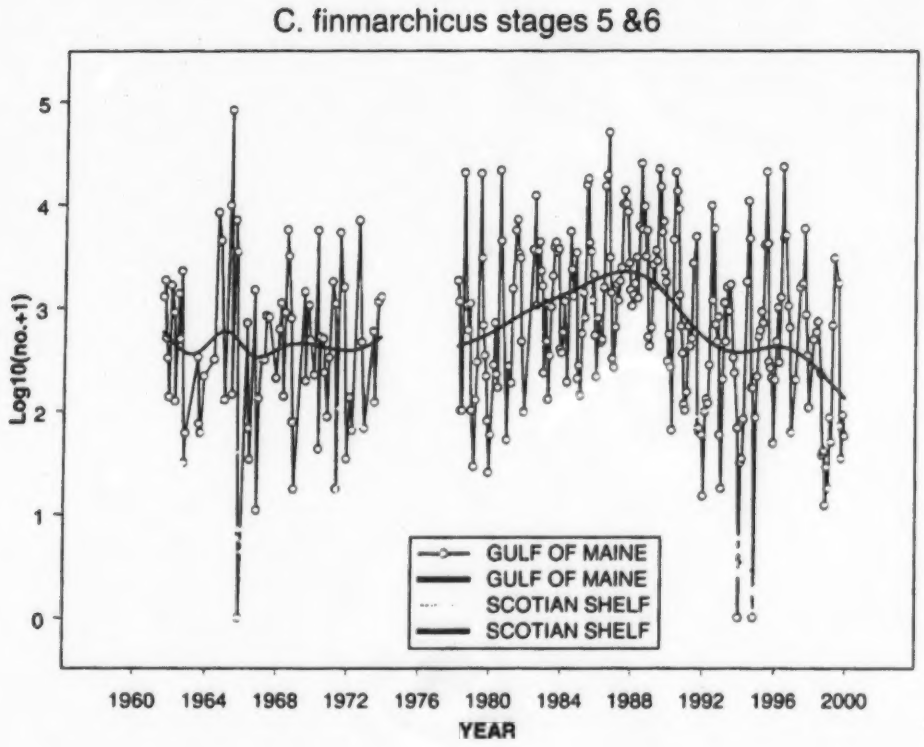


Figure 14: Time series of Calanus finmarchicus stages 5 and 6 from the Continous Plankton Recorder survey conducted in the Gulf of main and Scotian Shelf.

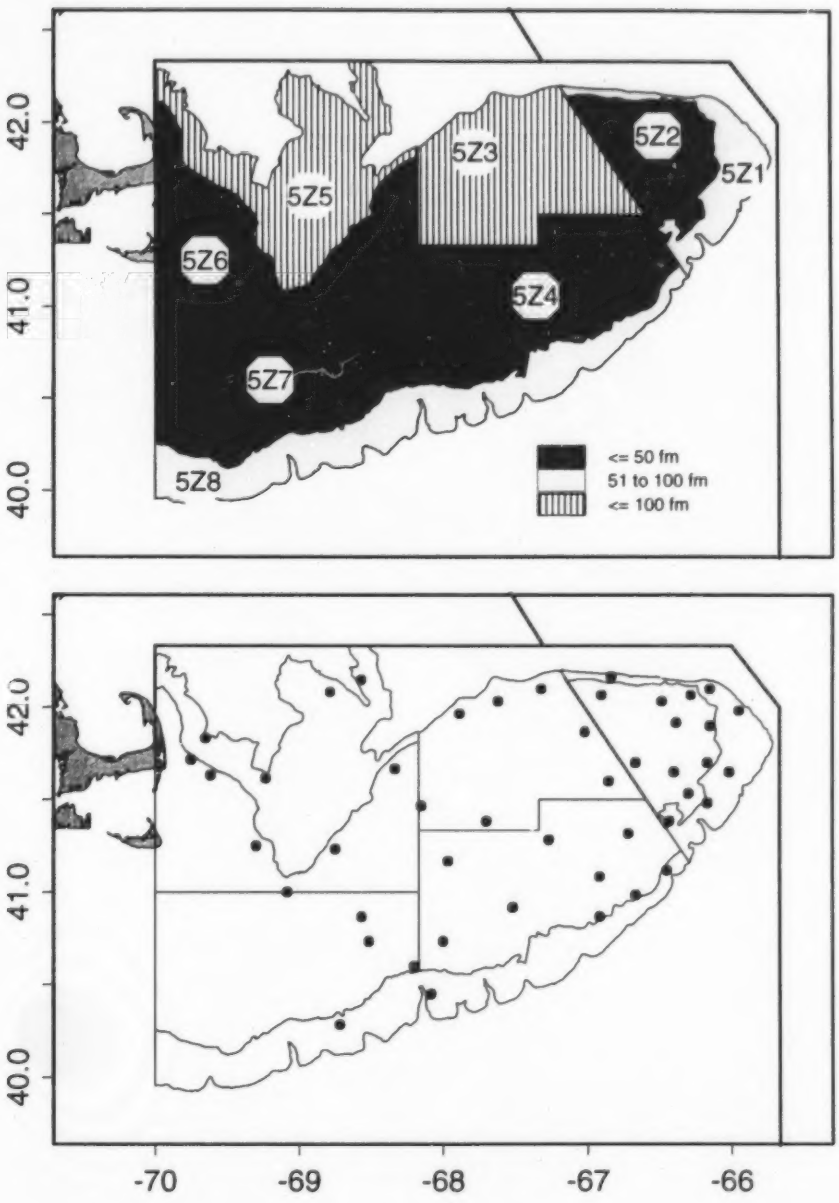


Figure 15: Map of Georges Bank showing the boundaries of the Canadian spring groundfish survey strata (top panel) and the location of the hydrographic samples taken in the 2000 survey.

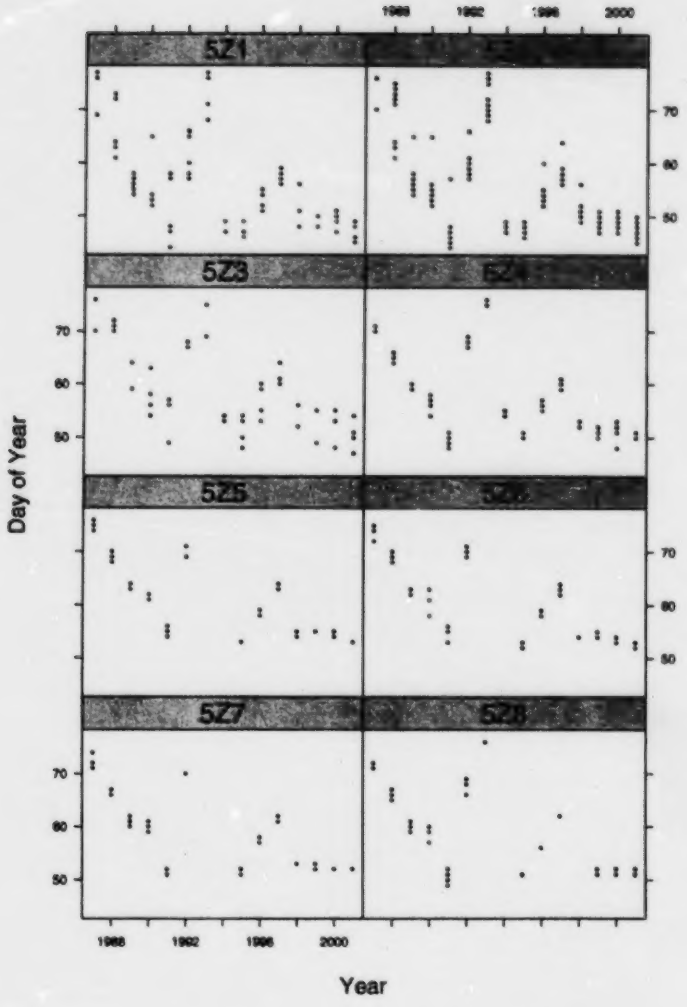


Figure 16: Timing of hydrographic samples taken during the Canadian spring groundfish surveys from 1987 to 2001.

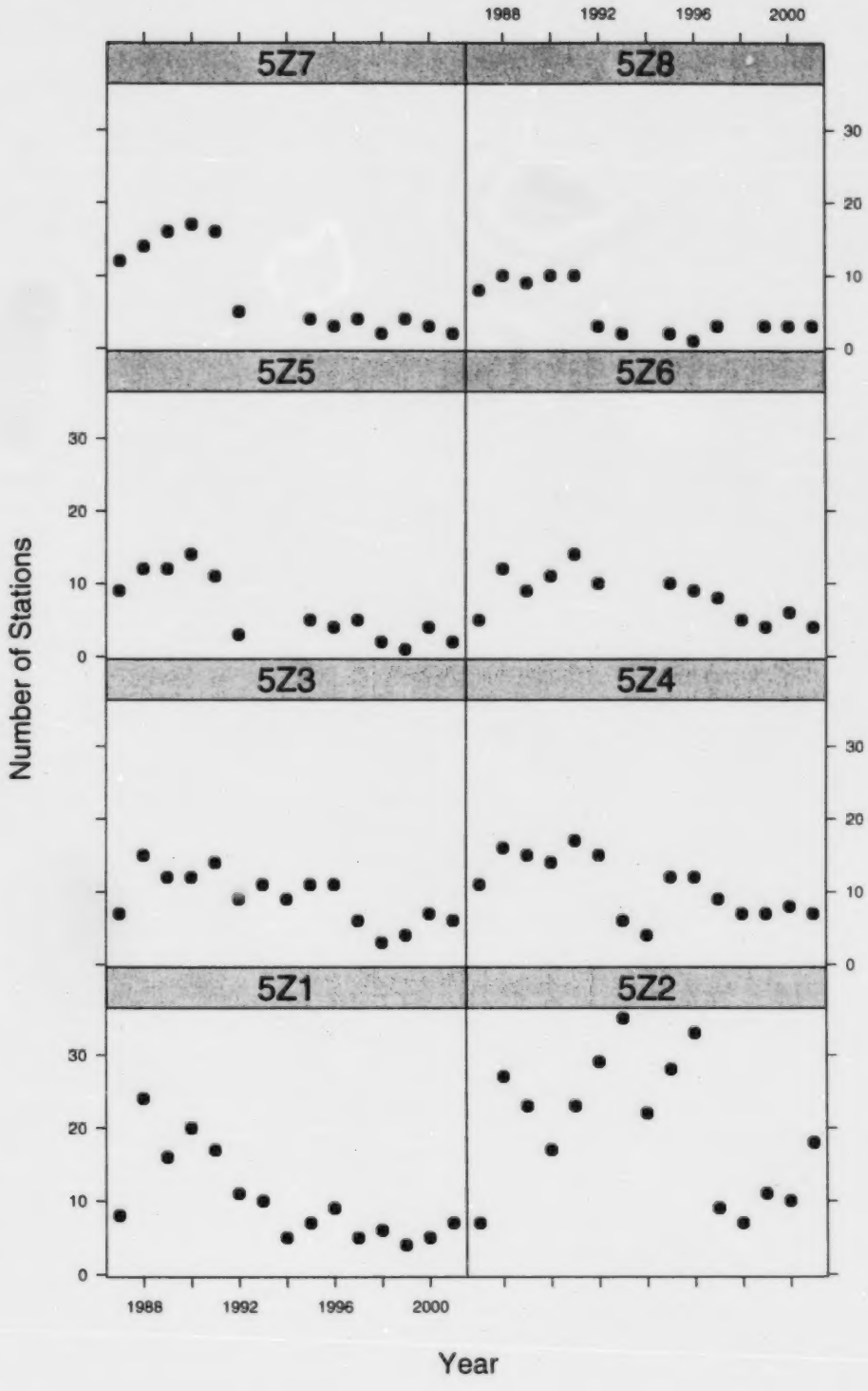


Figure 17: Number of hydrographic samples taken during the Canadian spring groundfish surveys from 1987 to 2001.

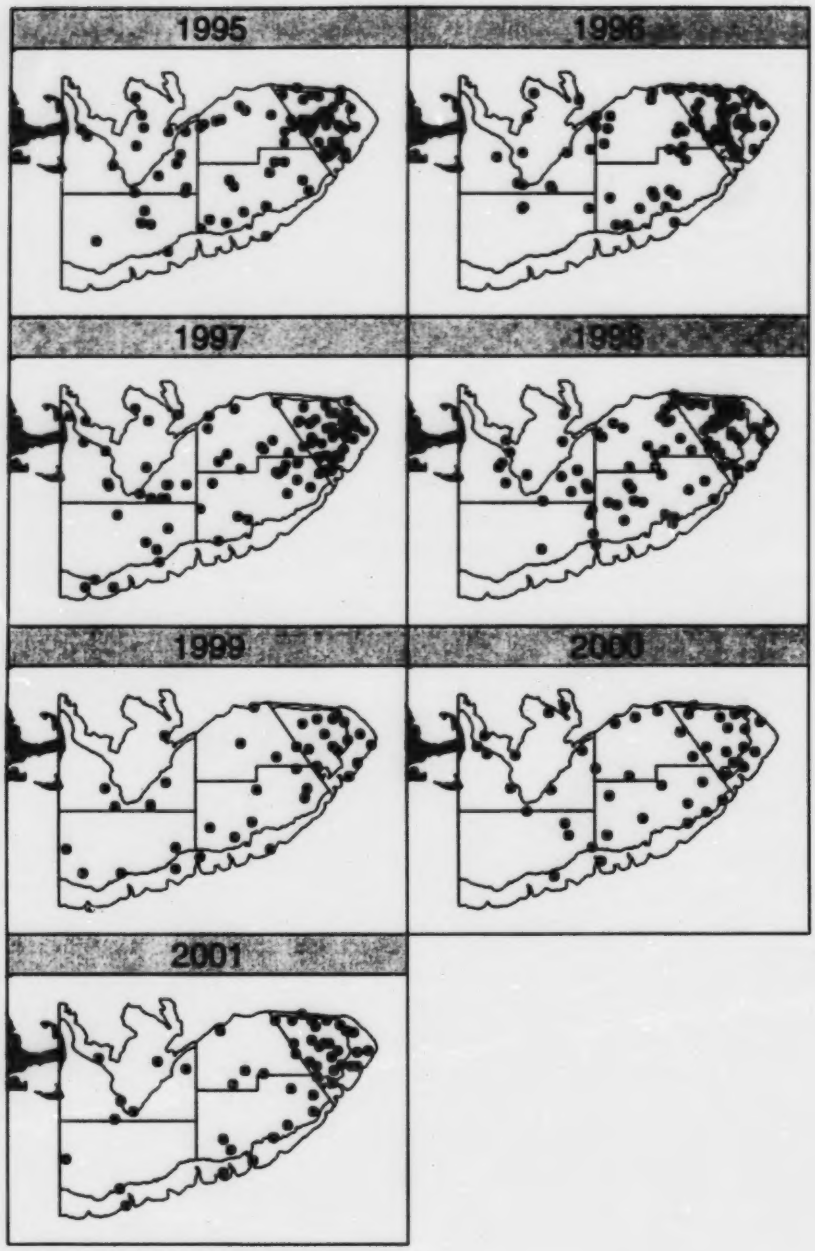


Figure 18: Spatial distribution of hydrographic samples taken during the Canadian spring groundfish surveys from 1987 to 2001.

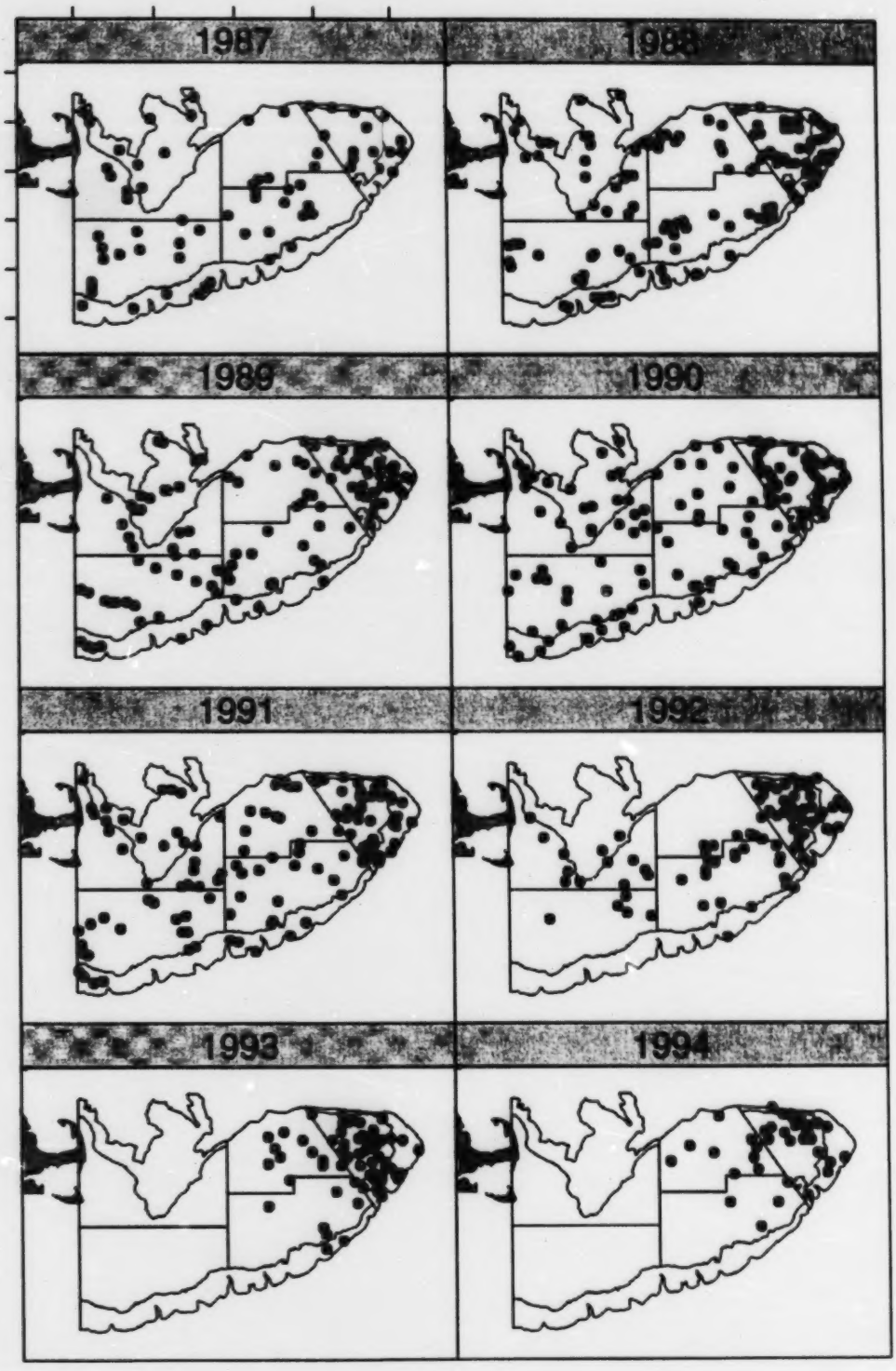


Figure 18 continued:

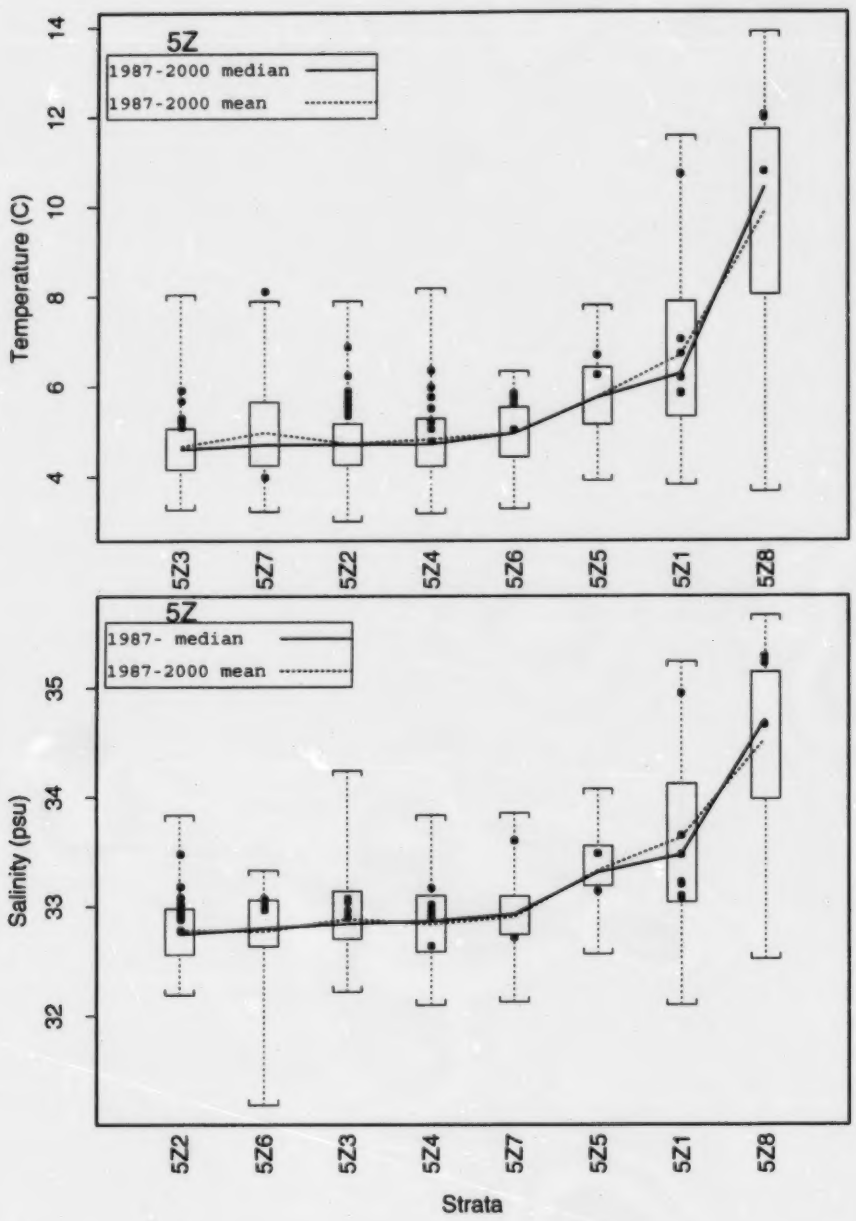


Figure 19: Box and whisker plot summarizing near-bottom temperatures (upper panel) and salinities (lower panel) by survey strata for the year 2001 (solid dots) and pervious years in the Canadian spring groundfish survey series (1987-2000). The boxes indicate the 25th and 75th percentiles. The ends of the whiskers are the minima and maxima.

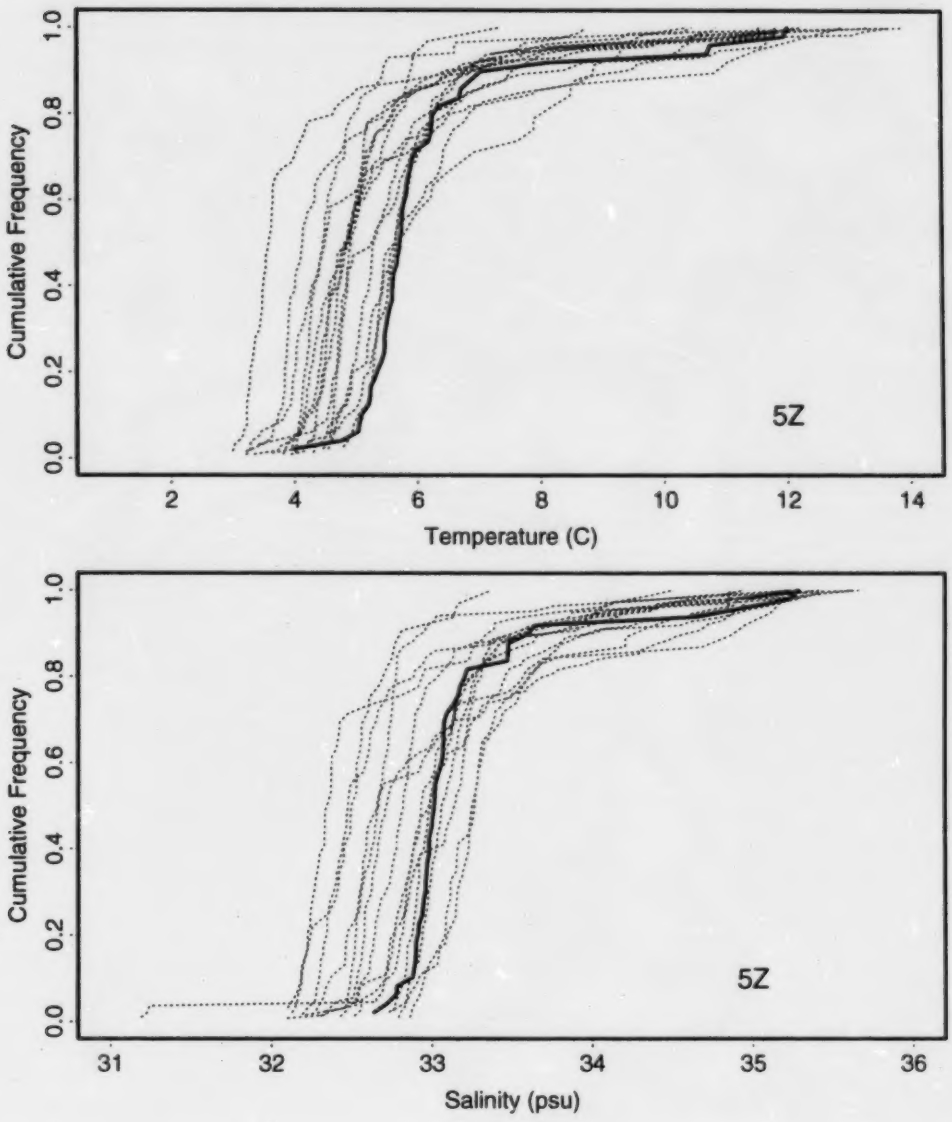


Figure 20: Cumulative frequency of near-bottom temperatures (upper panel) and salinities (lower panel) by survey strata for the year 2001 (solid curve) and pervious years in the Canadian spring groundfish survey series (dotted curves; 1987-2000). The cumulative frequencies are not weighted by stratum area.

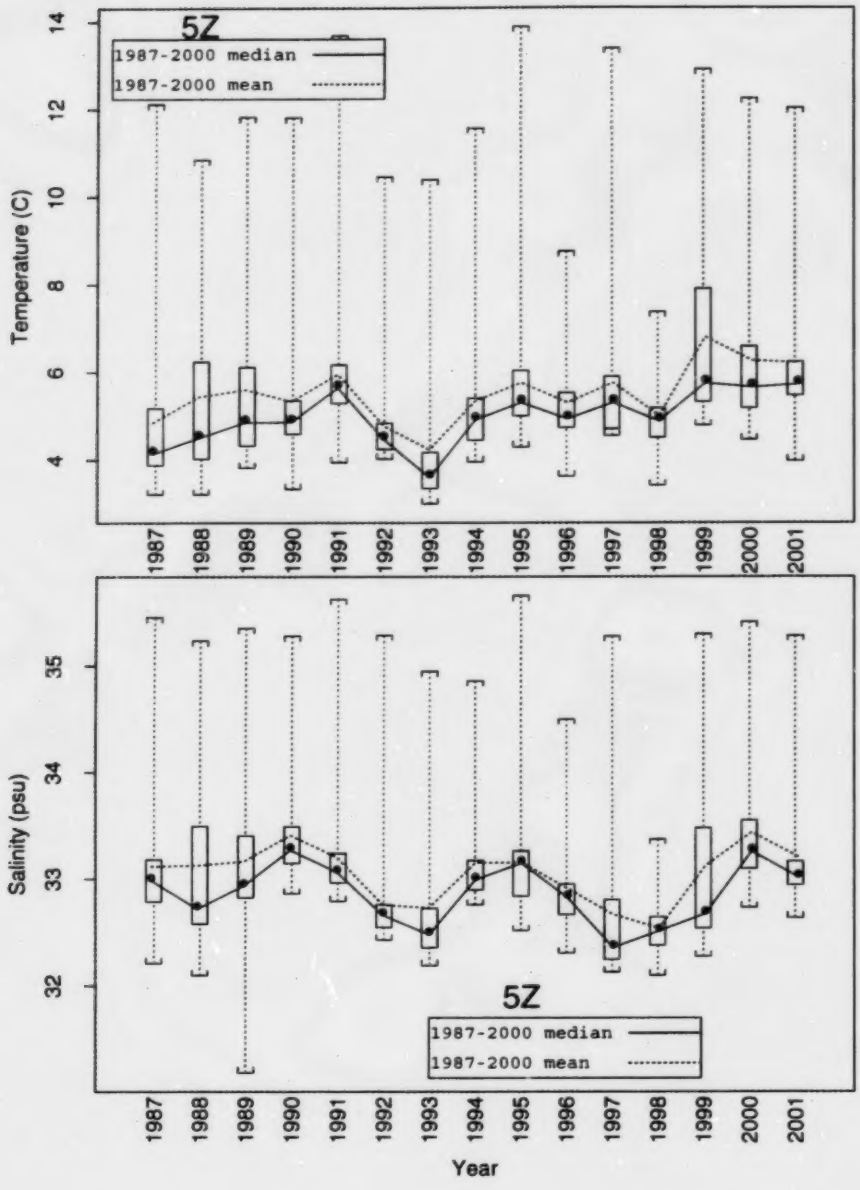


Figure 21: Time series of unweighted near-bottom temperatures (upper panel) and salinities (lower panel) observed in 5Z during the 1987-2001 Canadian spring groundfish survey series. Whiskers indicate the annual minima nad maxima. The boxes indicate the annual 25th and 75th quartiles. The dotted and solid lines connect the annual means and medians respectively.

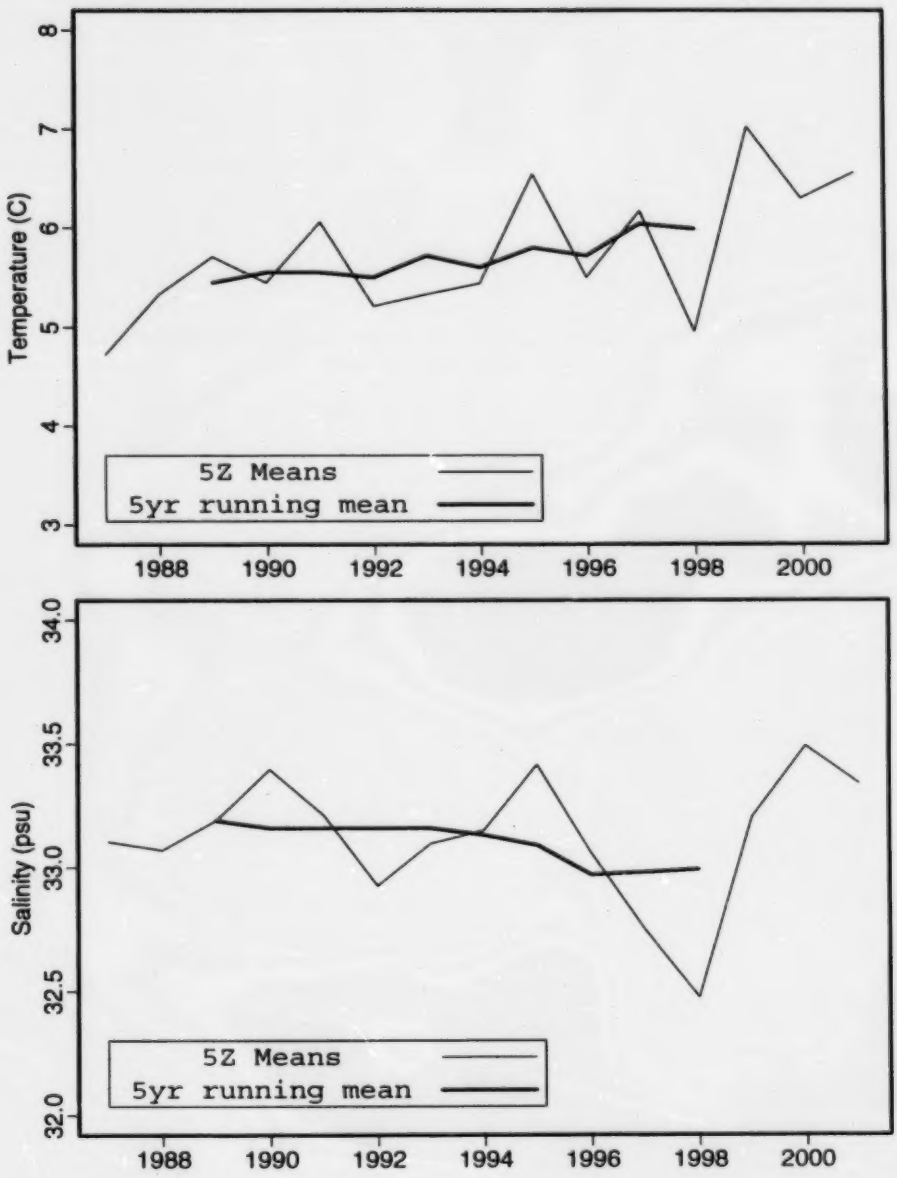


Figure 22: Time series of stratified mean near-bottom temperatures (upper panel) and salinities (lower panel) observed in 5Z during the 1987-2001 Canadian spring groundfish survey series. The thick line is a five year running mean of the annual stratified means (thin line).

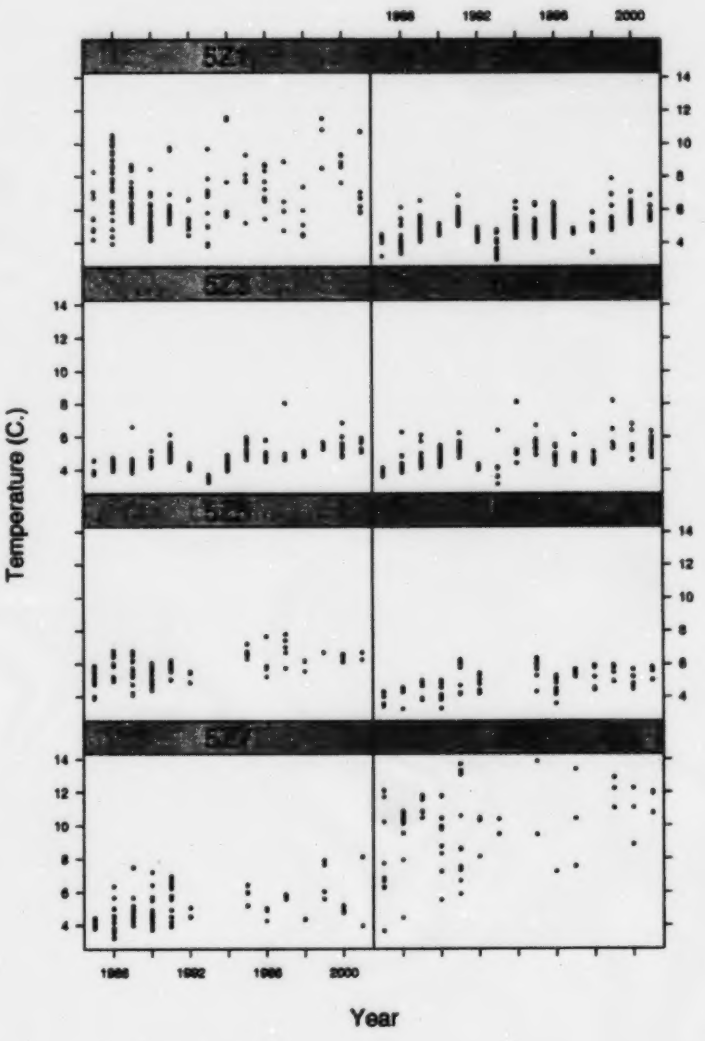


Figure 23: Strata specific time series of near-bottom temperatures observed in 5Z during the 1987-2001 Canadian spring groundfish survey series. Each dot represents a single observation.

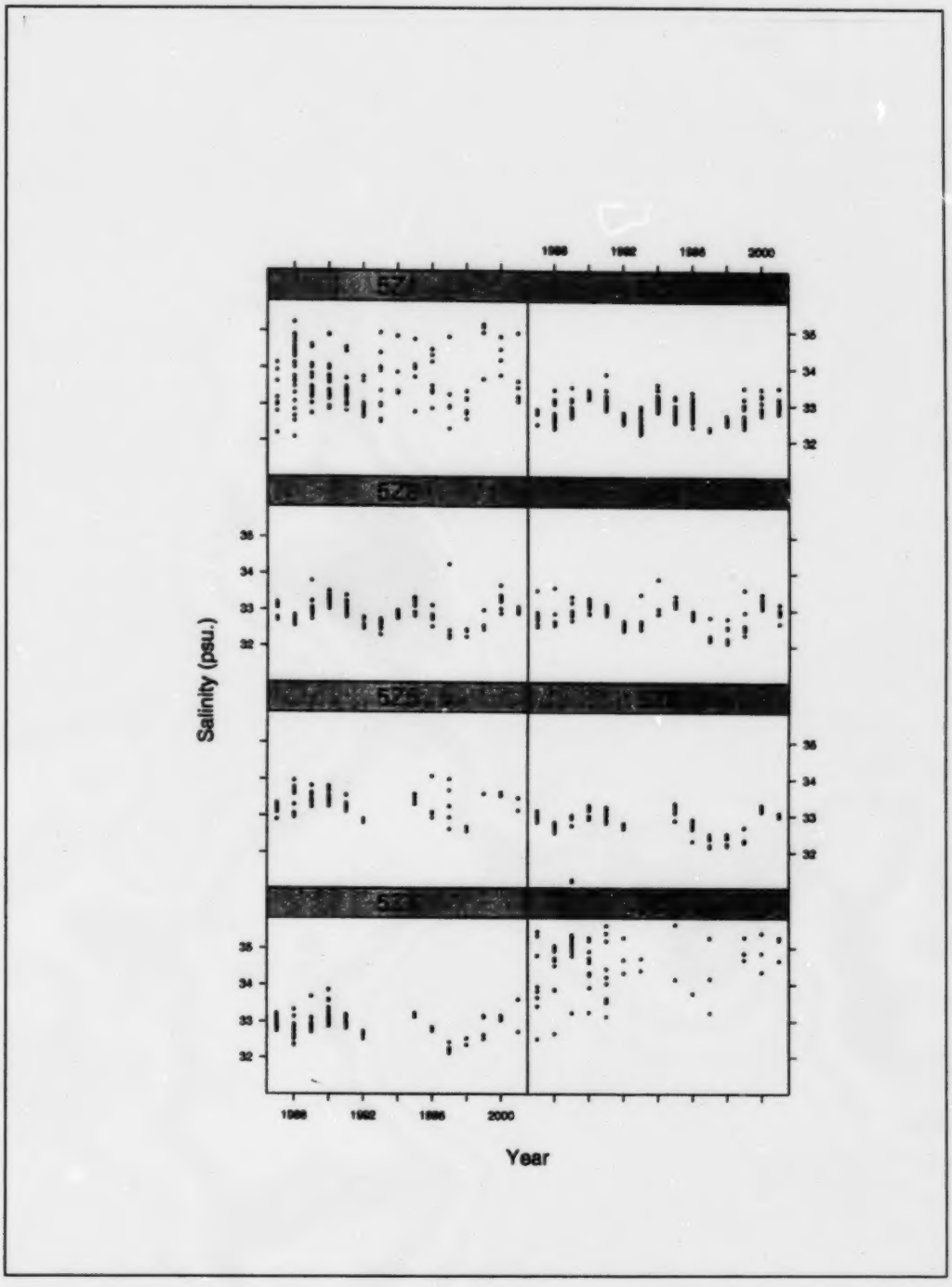


Figure 24: Strata specific time series of near-bottom salinities observed in 5Z during the 1987-2001 Canadian spring groundfish survey series. Each dot represents a single observation.